Segregating Data on the Flower Colour of *Pharbitis Nil.*

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CONTENTS.

Introduction.

This paper includes experimental data on the genetics of the general flower colour of *Pharbitis Nil,* and is intended to publish as supplementary to the writer's paper "The Property of the Genes Affecting the Flower Colour of *Pharbitis Nil*", which, being now in press, will soon appear in Journal of Genetics. The description of characters and the quotation from literature are given there.

I. White Flower.

WHITE-1.

On crossing white-1 with normal (coloured), the resultant F_1 hybrids, without exceptions, are normal. From such plants, the writer bred F_2 segregating as shown in Table 1.

Table 1.

F_2 from the cross between white-1 and normal.

Cross	+	w1	Total
3×324	64	20	84
SK×445	77	23	100
SK×440b	72	17	89
471×450	46	21	67
SE×E7	93	29	122
50×71-2	525	184	709
SK×450	96	19	115
470×426	108	41	149
470×450	110	34	144
3×50	385	130	515
3×N	218	72	290
324×71-2	333	106	439
Total	2127	696	2823

The segregation is in a 3 : 1 ratio of normal and white-1. In Table 2, an F_3 examination is given by summarizing the data.

Table 2.

F_3 of cross 3×50, showing segregation of white-1.

F_2 parent	No. families	+	w1	Total
Normal	13	366	......	366
	27	646	212	858
White-1	12	......	411	411

The F_3 results prove the simple recessiveness of white-1 to normal.

WHITE-2.

Owing to the recessive nature of white-2, the F_1 hybrids between white-2 and normal are normal. On selfing the hybrids thus obtained, the writer bred F_2 as shown by the data in Table 3.

Table 3.

F_2 from the cross between white-2 and normal.

Cross	+	w2	Total
322 × 318	45	16	61
323 × 318	81	32	103
455 × 480	102	37	139
460 × 481	75	49	124
74-2 × WO	79	25	104
450 × 74-2	70	26	96
420 × 34	240	85	325
450 × 45	124	48	172
415 × 78	173	57	230
316 × 410	44	19	63
316 × BK	198	67	265
322 × 50	452	149	601
M3 × NN	139	44	183
Total	1822	644	2466

The simplicity of white-2 in relation to normal is proved by F_3 data, which are collected in Table 4.

Table 4.

F_3 of cross 322 × 50, showing segregation of white-2.

F_2 parent	No. families	+	w2	Total
Normal	4	203	.....	203
	7	338	110	448
White-2	3	......	121	121

The dominant allelomorphs of white-1 and white-2 being complementary in the production of anthocyanin pigment in the corolla, the F_1 hybrids between white-1 and white-2 bear reversional normal flowers. Such hybrids gave F_2 as shown in Table 5.

The proportion of the three types, normal, white-1 and white-2, is nearly 9 : 3 : 4, indicating a dihybrid segregation. As regards the flower colour, the result is of a 9 : 7 ratio of normal and white. In Table 6 are shown F_3 data obtained by one of crosses shown in the previous table.

Table 5.

F_2 from the cross between white-1 and white-2, showing a 9:3:4 ratio.

Cross	+	w1	w2	Total
3×319	30	10	12	52
D×319	377	123	166	666
3×365	191	69	88	348
297×E7	82	22	33	137
3×316	267	91	125	483
170×319	208	67	83	358
Total	1155	382	507	2044

Table 6.

F_3 of cross D×319, showing segregation of white-1 and white-2.

F_2 parent	No. families	+	w1	w2	Total
Normal	4	110	......	......	110
	8	188	61	......	249
	7	254	......	85	339
	19	361	120	152	633
White-1	4	......	98	......	98
	8	......	189	60	249
White-2	13	......	......	302	302

White-1 may be concealed by white-2, therefore some white-2 offspring will be double recessive for white-1 and white-2. The white-2 F_3 segregated in the white-1 families invariably should be w1 w2. When white-2 of white tube is used as a partner of white-1 in hybridization, the white-2 segregates in the later generations have white tubes. This was the case, for instance, in the cross shown by the data in Table 6. However, when white-2 of coloured tube is crossed with white-1, the white-2 segregates have invariably coloured tubes, if there is no segregation for some tube-pattern genes such as tube-white or half-white. Sometimes nearly white tubes are found in white flowers, but this may be due to the influence of certain flower colour genes, which dilute also the colour of tubes. In such cases, the demarcation of the tube colour is difficult, and erroneously may be recorded as white tubes. The double recessive white form, that is w1 w2, has always a white tube. Therefore, when white-2 of coloured tube is crossed with white-1, and there is no extreme dilution of tube colour in the white-2 F_2 segregates, we should obtain a phenotypic distribution of 9 normal : 3 white-1 : 3 white-2 : 1 white-1 white-2 in proportion. In Table 7 are shown such F_2 obtained.

Table 7.

F_2 from the cross between white-1 and white-2, showing a 9:3:3:1 ratio.

Cross	+	w1	w2	w1 w2	Total
3×323	239	78	85	27	429
322×D	185	63	61	20	329
Total	424	141	146	47	758

The theory proposed above is proved by an F_3 examination, which is found by the data in Table 8.

Table 8.

E_3 of cross 3×323, showing segregation of white-1 and white-2.

F_2 parent	No. families	+	w1	w2	w1 w2	Total
Normal	8	76	......	......	......	76
	11	126	45	......	......	171
	18	259	......	86	......	345
	26	338	95	111	33	577
White-1	5	......	112	......	......	112
	14	......	164	......	60	224
White-2	8	......	......	99	......	99
	14	......	......	205	80	285
White-1 white-2	6	......	......	......	51	51

The white-2 type when intercrossed usually gives white-2 flowers as F_1, but sometimes it results in coloured flowers. In Table 9 are shown F_2 from such coloured F_1.

Table 9.

F_2 of coloured F_1 from the cross between two white flowers with green stems.

Cross	+	w	Total
316×319	177	124	301
316×100	231	190	421
Total	408	314	722

The results indicate that two complemental genes are working therein. This fact shows further complication of the genotype of the so-called white-2 flowers. Therefore the genetics of the white-2 character must be investigated further.

WHITE-3.

The white-3 character is also recessive to normal, and is segregated one-fourth in F_2 as shown in Table 10.

Table 10.

F_2 from the cross between white-3 and normal.

Cross	+	w3	Total
500 × 65	705	247	953
50 × 500	389	130	519
500 × N	455	154	609
Total	1550	531	2081

In Table 11 are shown the F_3 results obtained by one of these crosses.

Table 11.

F_3 of cross 50 × 500, showing segregation of white-3.

F_2 parent	No. families	+	w3	Total
Normal	15	258	......	258
	28	818	270	1088
White-3	10	......	115	115

Therefore the gene white-3 results in a thorough white flower; that is, a green-stemmed white flower with white tube and white seed. When white-3 is crossed with white-2, F_1 is normal, and a dihybrid segregation ensues in F_2. Actual data are shown in Table 12.

Table 12.

F_2 from the cross between white-1 and white-3.

Cross	+	w1	w3	Total
500 × 170	167	57	75	299
500 × D	96	32	42	170
Total	263	89	117	469

The result is 9 normal : 3 white-1 : 4 white-3 in proportion. White-1 has no effect on the white-3 component in appearance When white-3 was crossed with white-2, F_1 obtained bore normal flowers; and in F_2, segregation occurred as to normal, white-2 and white-3, the data being shown in Table 13.

Table 13.

F_2 from the cross between white-2 and white-3.

Cross	+	w2	w3	Total
316 × 460	93	33	29	155
460 × 415	83	39	39	161
Total	176	72	68	316

White-2 is concealed in white-3, therefore the F_1 hybrids between them should give a 9 : 3 : 4 ratio as to the segregating F_2 forms. In some crosses, the genetics of the white flowers were found to be more complicated than the cases described above; the presentation of these data will be made in the future.

II. Flower Hues.

PURPLE.

The F_1 hybrids between purple and normal (blue) bear normal flowers, apparently the same as pure normals. In F_2, segregation occurs in a simple fashion, the data being collected in Table 14.

Table 14.

F_2 from the cross between purple and normal.

Cross	+	pr	Total
26 × PF	225	77	302
N × PF	120	37	157
P × 26	364	121	485
219 × N	168	54	222
Total	877	289	1166

In F_3 the expectation was fulfilled as shown by the data in Table 15.

Table 15.

F_3 of cross 26×PF, showing segregation of purple.

F_2 parent	No. families	+	pr	Total
Normal	11	545	......	545
	24	887	293	1180
Purple	8	......	322	322

Therefore, the behaviour of the gene purple is so simple in inheritance that it does not need any further comment.

MAGENTA.

In hybridization of magenta with normal, the F_1 plants bear normal flowers; and in the subsequent generation, a simple segregation occurs, the data being presented in Table 16.

Table 16.

F_2 from the cross between magenta and normal.

Cross	+	mg	Total
H15×N	187	73	260
N×M	550	180	730
M×26	327	111	438
Total	1064	364	1428

The F_3 data did not give any notable facts beyond expectation, the results proving the simple recessiveness of magenta to normal, as shown by the data in Table 17.

Table 17.

F_3 of cross H15×N, showing segregation of magenta.

F_2 parent	No. families	+	mg	Total
Normal	9	366	......	366
	17	542	180	722
Magenta	8	......	235	235

With the experiments above shown, both flower colours, purple and magenta, are proved to be recessive to normal. Therefore, when purple is crossed with magenta we have F_1 bearing normal flowers, by the meeting of the two dominant allelomorphs of purple and magenta. Experimentally this was proved by obtaining normal F_1 from both reciprocal crossings of purple and magenta, and in F_2 a dihybrid segregation occurred as indicated by the data in Table 18.

Table 18.

F_2 from the cross between purple and magenta.

Cross	+	pr	mg	pr mg	Total
PF × M4	466	157	160	50	833
WII × H180	94	32	29	10	165
Total	560	189	189	60	998

The double recessive is "red" in colour. The "red" flower being genetically purple magenta, such a dihybrid segregation will also be obtained in F_2 when "red" is crossed with normal. Table 19 contains the F_2 data thus obtained.

Table 19.

F_2 from the cross between purple magenta and normal.

Cross	+	pr	mg	pr mg	Total
26 × UN	244	96	67	28	435

An F_3 examination of this cross was made and the data obtained are shown in Table 20.

Table 20.

F_3 of cross 26 × UN, showing segregation of purple and magenta.

F_2 parent	No. families	+	pr	mg	pr mg	Total
Normal	3	50	......	......	......	50
	11	296	119	......	......	415
	9	264	......	71	......	335
	26	532	187	168	47	934
Purple	7	......	183	......	......	183
	8	......	277	......	75	352
Magenta	4	......	......	117	......	117
	4	......	......	37	15	52
Purple magenta	1	......	......	......	44	44

The results did not give any new facts beyond expectation. As purple magenta differs in one gene to purple, we should expect purple F_1 and a segregation of 3 purple: 1 purple magenta in F_2, when it was crossed with purple. The F_2 frequency thus obtained is indicated in Table 21.

Table 21.

F_2 from the cross between purple magenta and purple.

Cross	pr	pr mg	Total
H180 × 50	175	60	235
P × D15	75	24	99
Total	250	84	334

The monogenic segregation will also be obtained when purple magenta is crossed with magenta, as shown in Table 22.

Table 22.

F_2 from the cross between purple magenta and magenta.

Cross	mg	pr mg	Total
50 × M4	384	131	515
455 × BK	141	41	182
Total	525	172	697

By these experiments we understand definitely that the "red" flowers are genetically purple magenta; or, in other words, purple and magenta give a unique flower colour by their combination. In hybridization of purple magenta with white-1, F_1 obtained was normal; and in F_2, segregation occurred as shown in Table 23.

Table 23.

F_2 from the cross between purple magenta and white-1.

Cross	+	pr	mg	pr mg	w1	Total
50 × 71-2	293	102	96	34	184	709

Therefore, the white-1 parent used in this crossing must be double dominant for purple and magenta, and contributed them to the F_1 zygotes in hybridization, resulting in normal blue flowers. The similar F_2, with an additional segregation of white-2, was observed as shown by the data in Table 24.

Table 24.

F_2 from the cross between white-1 and white-2.

Cross	+	pr	mg	pr mg	w1	w2	Total
3×365	100	40	38	13	69	88	348

The constitution of the white-1 parent (No. 3) is known to contain w1 W2 Pr Mg by the other crossing experiments, therefore that of its partner, white-2 (No. 365), should be W1 w2 pr mg.

DUSKY.

Crossing dusky with normal gives normal F_1 flowers; and in F_2, segregation occurs into normal and dusky in a simple ratio, as shown by the data in Table 25.

Table 25.

F_2 from the cross between dusky and normal.

Cross	+	dy	Total
K15×N	112	37	149
N8×K15	370	121	491
Total	482	158	640

The record of an F_3 examination is collected in Table 26.

Table 26.

F_3 of cross N8×K15, showing segregation of dusky.

F_2 parent	No. families	+	dy	Total
Normal	6	111	......	111
	10	183	58	241
Dusky	3	......	55	55

The results above shown came up to our expectation, therefore we need not comment any further in this connection. In Table 27 is shown an F_2 of the normal hybrids obtained by crossing magenta dusky with white-1, showing segregation of magenta, dusky and white-1.

Table 27.

F_2 from the cross between magenta dusky and white-1.

Cross	+	mg	dy	mg dy	w1	Total
324×71-2	194	61	58	20	106	439

The F_3 was examined, and the resultant data are shown collectively in Table 28.

Table 28.

F_3 of cross 324×71-2, showing segregation of magenta, dusky and white-1.

F_2 parent	No. families	+	mg	dy	mg dy	w1	Total
Normal	2	22	......	......	......	4	26
	7	135	50	......	......	......	185
	2	21	9	......	......	10	40
	3	56	......	12	......	......	68
	1	5	......	1	......	2	8
	2	18	10	11	1	......	40
	5	93	29	34	10	56	222
Magenta	1	......	33	......	......	......	33
	1	......	29	......	......	4	33
	3	......	63	......	24	......	87
	1	......	7	......	1	1	9
Dusky	2	......	......	40	12	......	52
	4	......	......	114	36	45	195
Magenta dusky	1	......	......	......	6	......	6
	2	......	......	......	61	25	86
White-1	10	......	......	......	......	301	301

The results of Table 28 show that the trihybrid expectation covers perfectly the data obtained. In Table 29 is shown an F_2 segregating purple, magenta and dusky.

Table 29.

F_2 from the cross between dusky and purple magenta.

Cross	+	pr	mg	pr mg	dy	pr dy	mg dy	pr mg dy	Total
K15 × 50	142	48	47	15	43	16	14	4	329

Owing to the free assortment of the three genes, the segregating forms appeared in accordance with a normal trihybrid ratio.

DUSKISH.

The F_1 hybrids between duskish and normal bear normal flowers, and segregation occurs into 3 normal : 1 duskish in F_2, as shown by the data in Table 30.

Table 30.

F_2 from the cross between duskish and normal.

Cross	+	dk	Total
428b × N	360	115	475
26 × 428b	275	88	363
Total	635	203	838

Therefore, duskish is a simple recessive to normal. One cross made between two strains (No. 316 and No. 100) having the white-2 character gave normal F_1 as mentioned before; and in F_2, segregation occurred in a wide range of colour intensity. On account of the fact that the segregates contained some which were very faintly coloured, the distinction of the minor variations in the flower colour was much confused. So the data are collected into three major classes, normal, duskish and white, as shown in Table 31.

Table 31.

F_2 from the cross between two whites, segregating duskish.

Cross	+	dk	w	Total
316 × 100	171	60	190	421

Owing to the occurrence of very faintly coloured flowers, duskish was sometimes apparently white. In such cases the writer made observations on the colour of the corolla by opening full-grown buds, in which process the least amount of the colour is greatly exaggerated.[1] In Table 32 are shown F_2 obtained by the cross between purple magenta duskish and white-1.

Table 32.

F_2 from the cross between purple magenta duskish and white-1.

Cross	pr	pr mg	pr dk	pr mg dk	w1	Total
470×426	62	24	19	3	41	149
1-1×426	130	43	40	15	73	301
Total	192	67	59	18	114	450

Because of the fact that duskish is not allelomorphic to dusky, F_1 flowers obtained by the cross between dusky and duskish are normal, reverted by the meeting of their two complemental dominant genes. In Table 33 is shown such a case by the actual data, in which, however, purple was contained commonly by both parents, therefore the F_1 flowers were purple in colour.

Table 33.

F_2 from the cross between purple dusky and purple magenta duskish.

Cross	pr	pr mg	pr dy	pr mg dy	pr dk	pr mg dk	Total
430×425b	84	32	30	11	29	13	199

In this cross the segregating genes are magenta, dusky and duskish. Owing to the hypostatic nature of dusky to duskish, the segregating proportion should be 27 purple: 9 purple magenta: 9 purple dusky: 12 purple duskish: 3 purple magenta dusky: 4 purple magenta duskish. The observed numbers, however, show much deficit in the frequency of duskish classes. This dificit relates to the mutating nature of duskish, because the duskish parent used in this cross was a "ruled" variant.

III. Flower Tones.

Intense.

Intense behaves as recessive to normal. In F_2 of normal F_1 obtained

1) The method is also useful for faded when the colour is faint.

by the cross between intense and normal, segregation occurred into 3 normal to 1 intense as shown in Table 34.

Table 34.

F_2 from the cross between intense and normal.

Cross	+	i	Total
RF × BK	85	33	118
B × F6	146	53	199
475 × F6	70	19	89
Total	301	105	406

Table 35 contains F_2 data obtained by the hybridization of intense and magenta.

Table 35.

F_2 from the cross between intense and magenta.

Cross	+	mg	i	mg i	Total
B × BK	206	77	66	22	371
ID × BK	81	27	29	7	144
475 × BK	83	17	19	6	125
Total	370	121	114	35	640

The segregation is related to the genes, magenta and intense. With these crossing experiments the simple recessive nature of intense to normal is well elucidated.

LIGHT-1.

Two light flowers are found, differing genetically but giving a similar tone; one of them, light-1, is rather closely linked with yellow and dusky, but the other, light-2, is transmitted independently to dusky.

In Table 36 is indicated the linked segregation of light-1 and dusky.

Table 36.

F_2 from the cross between magenta light-1 and magenta dusky.

Cross	mg i	mg lt1	dy i	dy lt1	Total
422 × 435	94	34	45	0	173

Therefore, light-1 acts as a recessive to intense. The similar data are collected in Table 37, in which, however, an additional segregation for purple occurred.

Table 37.

F_2 from the cross between light-1 and purple dusky intense.

Cross	i	lt1	dy i	dy lt1	pr i	pr lt1	pr dy i	pr dy lt1	Total
421 × 430	70	24	34	0	22	8	11	0	169

These results show close linkage between dusky and light-1.

LIGHT-2.

Light-2 is the other diluting gene for intense. In Table 38 are shown F_2 obtained by crossing light-2 with intense.

Table 38.

F_2 from the cross between light-2 and intense.

Cross	i	lt2	Total
220 × A	264	86	350
UN × 220	217	71	288
Total	481	157	638

Table 39 contains another cross, showing dihybrid segregation for magenta and light-2.

Table 39.

F_2 from the cross between purple intense and purple magenta light-2.

Cross	pr i	pr lt2	pr mg i	pr mg lt2	Total
65 × 220	199	79	76	16	370

The light-2 parents in the crosses shown in Tables 38 and 39 are considered to be light-2 intense as to the genes affecting the flower tone. Therefore, we had monohybrid segregation for the intensity of the flower colour. In Table 40 is shown an independent segregation of light-2 to dusky.

Table 40.

F_2 from the cross between purple magenta dusky intense and purple magenta light-2.

Cross	pr mg i	pr mg lt2	pr mg dy i	pr mg dy lt2	Total
324×220	375	126	123	42	666

The free assortment of light-2 to dusky gives a decided proof for the occurrence of another recessive light gene, besides light-1, which is strongly linked with dusky.

DILUTE AND TINGED.

On account of close linkage of white-2 with Dilute, the hybridization of white-2 plants results in Dilute flowers among its F_2 segregates. In Table 41 is presented an F_2 making segregation of Dilute.

Table 41.

F_2 from the cross between white-2 and normal, segregating Dilute and tinged.

Cross	+	D	tg	w2	Total
455×480	21	52	29	37	139

In this case another segregation for tinged occurred. The respective parental genotypes are D tg w2 for white-2, and + or d Tg W2 for its partner. Owing to close linkage between Dilute and white-2, the segregating ratio of normal, Dilute and tinged was nearly 1 : 2 : 1. In Table 42 is shown a similar F_2, with an additional segregation of white-3.

Table 42.

F_2 from the cross between white-2 and white-3, segregatin Dilute and tinged.

Cross	+	D	tg	w2	w3	Total
460×481	21	38	16	23	26	124

The close linkage between Dilute and white-2 was also the case, and gave a segregating ratio of high repulsion in the distribution of the coloured and white-2 flowers.

IV. Flower Patterns.

Speckled.

Speckled acts as a recessive character to normal, and is segregated in one-fourth of F_2, the data observed being collected in Table 43.

Table 43.

F_2 from the cross between speckled and normal.

Cross	+	sp	Total
350×N	255	86	341
350×26	211	70	281
Total	466	156	622

An F_3 examination was recorded by cross 350×26, the data obtained being presented in Table 44.

Table 44.

F_3 of cross 350×26, showing segregation of speckled.

F_2 parent	No. families	+	sp	Total
Normal	8	155	......	155
	13	398	128	526
Speckled	6	......	89	89

In Table 45 are shown F_2 data, containing segregation of speckled, with additional assortments of magenta and white-1.

Table 45.

F_2 from the cross between white-1 and magenta speckled.

Cross	+	mg	sp	mg sp	w1	Total
SK×445	35	16	24	2	23	100

The surplus of speckled is due to close linkage between white-1 and speckled. In Table 46 is indicated an F_2, in which segregation occurred as to speckled and purple.

Table 46.

F_2 from the cross between magenta and purple magenta speckled.

Cross	mg	mg sp	pr mg	pr mg sp	Total
187×921	67	23	20	7	117

Table 47 contains the results from another cross showing segregation of duskish and speckled.

Table 47.

F_2 from the cross between purple magenta duskish and purple magenta speckled.

Cross	pr mg	pr mg sp	pr mg dk	pr mg dk sp	Total
189×921	164	64	54	12	294

With the results above presented, the simple recessive nature of speckled is clear. The common white-2 flowers carry no speckled gene, therefore the tube colour, if present, is distributed uniformly; that is, not speckled. Whereas, if it carries the gene speckled, we may have a white flower with speckled tube, which is genotypically w2 sp. In hybridization of white-2 with coloured tube by speckled with speckled tube, F_1 obtained was normal; and in F_2, segregation occurred as shown in Table 48, in which white flowers with speckled tubes appeared.

Table 48.

F_2 from the cross between white-2 and speckled, segregating white-2 speckled.

Cross	+	sp	w2	w2 sp	Total
350×323	94	22	38	6	160

Although the deficit of speckled segregates is remarkable, the data show a dihybrid distribution. The double recessive form, that is w2 sp, is a white flower with speckled tube, as the white parent was of coloured tube. In Table 49 are shown the F_3 results obtained.

Table 49.

F_3 of cross 350 × 323, showing segregation of white-2 speckled.

F_2 parent	No. families	+	sp	w2	w2 sp	Total
Normal	9	152	......	......	......	152
	14	241	61	......	......	302
	18	285	......	101	......	386
	23	221	59	70	13	363
Speckled	2	......	9	......	......	9
	4	......	22	......	11	33
White-2	7	......	......	74	......	74
	17	......	......	241	79	320
White-2 speckled	4	......	......	......	31	31

In general, the deficit of speckled segregates is also remarkable in F_3, but its significance is unknown.

SPECKLED-REDUCED.

On crossing speckled-reduced with speckled, F_1 obtained is speckled; and in F_2, segregation occurs in a simple fashion. The actual F_2 data are shown in Table 50.

Table 50.

F_2 from the cross between speckled and speckled-reduced.

Cross	sp	sp-r	Total
410 × 445	95	35	130
410 × 449	80	27	107
Total	175	62	237

In Table 51 are shown F_2 obtained by the hybridization of speckled-reduced and normal, a dihybrid segregation taking place here.

Table 51.

F_2 from the cross between speckled-reduced and normal.

Cross	+	sp	sp-r	Total
410 × 190	274	63	28	365
410 × 26	171	41	13	225
Total	445	104	41	590

The segregation occurred into 12 normal : 3 speckled : 1 speckled-reduced in proportion. An F_3 examination was made by one of these crosses, and the results are shown by the data in Table 52.

Table 52.

F_3 of cross 410×26, showing segregation of speckled and speckled-reduced.

F_2 parent	No. families	+	sp	sp-r	Total
Normal	10	355	......	......	355
	4	177	60	......	237
	9	333	84	27	444
Speckled	2	......	34	......	34
	4	......	78	25	103
Speckled-reduced	3	......	......	22	22

By the qualifying nature of speckled-reduced for speckled, the gene speckled-reduced has no effect on the Sp genotype.

The background colour of the corollas of speckled-reduced may be yellowish or pale, with nearly all gradations extending to white. Owing to the occurrence of some quantitative variation in the intensity of the background colour, the classification of the segregates and the identification of the genes working therein are difficult in the hybrid progeny in general. The yellowish background colour of the corolla is due to flavon contained in the cells, and the fine spots occurring on the same corolla to the anthocyanin pigment. However, in the hybrid progeny of a cross made between white-1 and intense speckled was presented a sharp demarcation in the intensity of the yellowish background of speckled-reduced. The segregation occurred simultaneously as to white-1, speckled and speckled-reduced, the F_2 obtained being presented in Table 53.

Table 53.

F_2 from the cross between white-1 and intense speckled, showing two types of background colour.

Cross	+	i	w1	sp	i sp	sp w1	sp-r	i sp-r	sp-r w1	Total
3×350	43	16	29	11	5	0	6	2	0	112

Out of the genes segregated in this hybridization, white-1 and speckled-reduced came of the white-1 parent, and the other two genes, intense and speckled, were contributed by its partner. The gene intense is also effective to the flavon colour itself, exhibiting much intense yellowish background to be recessive to its normal dilute background. The other points in this segregation are already familiar from the previous description. The F_3 data are shown collectively in Table 54.

Table 54.

F_3 of cross 3×350, showing segregation of white-1, speckled, speckled-reduced and intense.

F_2 parent	No. families	Genotype	+	i	w1	sp	sp i	sp w1	sp-r	i sp-r	w1 sp-r	Total
Normal	5	+/w1 + +/sp +	31	......	19	14	......	0	......	......	......	64
	3	+/w1 + sp +/sp-r	13	......	8	......	......	......	10	......	0	31
	5	+/w1 +/i +/sp +	36	11	25	17	4	0	......	......	......	93
	3	+/w1 + +/sp +/sp-r	39	......	22	17	......	0	6	......	0	84
	2	+/w1 +/i sp +/sp-r	27	9	21	......	......	......	18	3	0	78
	3	+/w1 +/i +/sp +/sp-r	36	7	26	19	4	0	6	3	0	101
Intense	3	+/w1 i +/sp +	......	30	19	......	10	0	......	......	......	59
	4	+/w1 i sp +/sp-r	......	54	25	......	......	......	......	29	0	108
	3	+/w1 i +/sp +/sp-r	......	56	33	......	18	0	......	7	0	114
White-1	20	w1 ? ? ?	......	......	389	......	......	......	......	......	......	389
Speckled	2	+ + sp +/sp-r	......	......	......	32	......	......	12	......	......	44
Intense speckled	2	+ i sp +/sp-r	......	......	......	......	27	......	......	17	......	44
Speckled-reduced	1	+ + sp sp-r	......	......	......	......	......	......	21	......	......	21
	2	+ +/i sp sp-r	......	......	......	......	......	......	54	14	......	68
Intense speckled-reduced	1	+ i sp sp-r	......	......	......	......	......	......	......	16	......	16
	1	+/w1 i sp sp-r	......	......	......	......	......	......	......	7	3	10

On account of the small number of individuals contained, five families are omitted from this table.

In one F_3 family, No. 48. the segregation occurred into intense speckled-reduced and white with green stem. The mother plant of this family bore intense speckled-reduced flowers, and was heterozygous for white-1. Therefore, its genotype is i sp sp-r +/w1. Owing to the very close linkage between white-1 and speckled, the production of white flowers with spotted (sp) or green (sp-r) stems should be very rare. The appearance of such plants is due to crossing over between sp and w1. The writer calculated the frequency of recombination between them at roughly 0.8 per cent. from the relative possibility in the occurrence of such an unusual family.

FADED.

Faded behaves as a simple recessive to normal. In Table 55 are collected F_2 obtained by selfing normal hybrids from faded and normal.

Table 55.

F_2 from the cross between faded and normal.

Cross	+	fd	Total
$\beta\times 26$	408	133	541
$N\times\beta$	329	110	439
Total	737	243	980

An F_3 examination was made and the data obtained are shown in Table 56.

Table 56.

F_3 of cross $\beta\times 26$, showing segregation of faded.

F_2 parent	No. families	+	fd	Total
Normal	10	211	......	210
	18	363	118	481
Faded	7	......	82	82

Thus, faded differs by one gene to normal, which is dominant to the former. In Table 57 is indicated another F_2 showing a little complicated segregation.

Table 57.

F_2 from the cross between white-3 and white-2, segregating faded and Dilute.

Cross	+	D	fd	w2	w3	Total
461×415	21	44	18	39	39	161

The segregation occurred in regard to four genes, Dilute, faded, white-2 and white-3. Owing to the close linkage between Dilute and white-2, the segregating proportion is in part exhibiting an unusual distribution. Theoretically the parental constitutions are simple w3 for white-3, and D w2 fd for white-2 ; therefore we should obtain F_2 segregated into 18 Dilute: 9 normal: 9 faded: 12 white-2: 16 white-3 in proportion, when Dilute faded is classified together with faded in observation, because of difficulty in its demarcation. This expectation practically fulfills the data obtained. Table 58 contains one more F_2 segregated into faded, speckled, speckled-reduced and white-2.

Table 58.

F_2 from the cross between speckled-reduced and white-2, segregating faded.

Cross	+	fd	sp	sp fd	sp-r	w2	Total
410×415	41	13	12	4	5	28	103

The hybridization corresponds to cross sp sp-r × w2 fd, therefore we should obtain F_2 segregating 108 normal: 36 faded: 27 speckled: 9 speckled faded: 12 speckled-reduced (including speckled-reduced faded) 64 white-2 in proportion. The theory practically accords with the result obtained. The double recessive flower, speckled faded, has faded speckles with whitish centres.

Smeary.

Smeary is also a simple recessive to normal. In Table 59 are shown F_2 presenting this fact.

Table 59.

F_2 from the cross between smeary and normal.

Cross	+	fd^s	Total
M3×ID	179	62	241
26×M3	118	41	159
Total	297	103	400

In another cross the segregation occurred into smeary and white-2, the data of which are shown in Table 60.

Table 60.

F_2 from the cross between smeary and white-2.

Cross	+	fd^s	w2	Total
M3×NN	104	35	44	183

An F_3 examination of this cross was made and the data are summarized in Table 61.

Table 61.

F_3 of cross M3×NN, showing segregation of smeary and white-2.

F_2 parent	No. families	+	fd^s	w2	Total
Normal	1	60	......	......	60
	4	46	18	......	64
	10	215	66	......	281
	10	168	54	78	300
Smeary	1	......	47	......	47
	1	......	16	3	19
White-2	10	......	......	177	177

Two genes, smeary and white-1, are related to the segregation. Table 62 is concerned with F_2 segregating smeary and magenta.

Table 62.

F_2 from the cross between smeary and magenta.

Cross	+	fd^s	mg	mg fd^s	Total
M3×A5	136	40	37	14	227
M3×BK	151	57	72	13	293
Total	287	97	109	27	520

In Table 63 are indicated F_3 results of cross M3×A5 as the proof of dihybrid segregation of smeary and magenta.

Table 63.

F_3 of cross M3×A5, showing segregation of smeary and magenta.

F_2 parent	No. families	+	fd^s	mg	mg fd^s	Total
Normal	6	123	......	......	......	123
	11	232	84	......	......	316
	2	25	......	13	......	38
	15	204	70	74	18	366
Smeary	5	......	144	......	......	144
	11	......	189	......	68	257
Magenta	3	......	......	53	......	53
	9	......	......	180	47	227
Magenta smeary	1	......	.....	......	49	49

The F_2 frequency of another cross is shown in Table 64, which contains the segregating data for smeary, with simultaneous assortments of speckled and speckled-reduced.

Table 64.

F_2 from the cross between smeary and speckled-reduced.

Cross	+	fd^s	sp	sp-r	Total
M3×410	103	28	45	12	188

Three genes being concerned in this hybridization, the segregating ratio is theoretically 36 normal : 12 smeary : 12 speckled : 4 speckled-reduced or simply 9 : 3 : 3 : 1, as smeary speckled is classed under speckled in observation. Here a marked deviation is found in the middle classes, but we may pass it over without attaching any serious importance to it.

With the experimental results above shown, faded and smeary are allelomorphic to normal, and both characters manifest quantitative degrees of dilution in the flower colour Under such circumstances, faded and smeary may have the same location on a chromosome. On hybridization of faded with smeary, F_1 obtained bears smeary flowers without reverting to normal. Table 65 contains F_2 obtained from such a cross.

Table 65.

F_2 from the cross between faded and magenta dusky smeary.

Cross	fd^s	mg fd^s	dy fd^s	mg dy fd^s	fd	mg fd	dy fd	mg dy fd	Total
M3×β	71	37	20	5	22	9	10	3	117

The segregation occurred as to faded (*versus* smeary), magenta and dusky in a trihybrid fashion. Faded is a simple recessive to smeary, therefore the three forms, normal, smeary and faded, are allelomorphic to one another.

Rayed.

Rayed is an old variation acting as dominant to normal. In the course of experiments, the writer obtained Rayed mutants with characteristics similar to the old Rayed. Using this new Rayed, he made several crossings, the results of which are presented in Table 66.

Table 66.

F_2 obtained by using the duskish Rayed mutant in hybridization.

Cross	Ry	+	Ry dk	dk	Total	w1	w2
475×450	146	41	47	16	250	......	......
470×450	69	26	10	5	110	(34)	......
471×450	26	7	12	1	46	(21)	......
450×45	75	18	21	10	124	......	(48)
Total	316	92	90	32	530	......	......

Rayed and duskish being located quite apart in the same chromosome, practically a free assortment occurred between them. The parental duskish Rayed is a mutant form obtained in a duskish family. As stated elsewhere, the duskish Rayed compound results in a white flower, reducing the duskish colour of the corolla, though the rays are faintly coloured. Then, the results obtained by using the old Rayed in hybridization are as follows: No. 405 bore very faintly coloured (purple magenta dusky light-2) flowers with Rayed restriction. When this was crossed with No. 65, purple intense, the writer obtained F_1 bearing purple intense Rayed flowers. In Table 67 is shown an F_2 thus obtained.

Table 67.

F_2 from the cross between Rayed purple magenta dusky light-2 and purple intense.

Cross	pr Ry	pr i	pr lt2	pr mg i	pr mg lt2	pr dy i	pr dy lt2	pr mg dy i	pr mg dy lt2	Total
65×505	288	44	14	10	6	14	4	5	1	386

In preparation of the table, the writer has collected all Rayed compounds under the column of Rayed, because of difficulty in classification among them. In Table 68 are presented the summarizing F_3 data of this cross.

This hybridization gave segregation for Rayed, light-2, magenta and dusky, exhibiting a tetrahybrid distribution of the segregates. Outwardly the segregation is much complicated, but the genes are segregated independently of each other. In the Rayed flowers, a continuous gradation was found in the quantitative manifestation of the colour, extending to nearly white. In the non-Rayed flowers, however, the demarcation of

Table 68.

F_3 of cross 65×505, showing segregation of Rayed, light-2, magenta and dusky.

F_2 parent	No. families	pr Ry	pr i	pr lt2	pr mg i	pr mg lt2	pr dy i	pr dy lt2	pr mg dy i	pr mg dy lt2	Total
Purple Rayed	18	1022	......	......	......	......	......	......	......	......	1022
	2	78	27	......	......	......	......	......	......	......	105
	3	56	16	7	......	......	......	......	......	......	79
	2	91	23	5	6	1	......	......	......	......	126
	3	280	65	13	......	......	15	3	......	......	376
	1	8	2	......	0	......	1	......	1	......	12
	3	190	34	10	9	3	9	1	4	0	260
	1	23	......	6	......	......	......	2	......	......	31
	2	155	......	43	......	12	......	10	......	3	223
	3	71	......	......	26	......	......	......	......	......	97
	1	92	......	......	26	11	......	......	......	......	129
	1	60	......	......	14	......	......	......	4	......	78
	2	107	......	......	21	13	......	......	11	3	155
	1	80	......	......	......	21	......	......	......	6	107
	1	44	......	......	......	......	15	4	......	......	63
	3	252	......	......	......	......	36	24	11	6	329
Purple intense	1	......	55	19	......	......	......	......	......	......	74
	1	......	26	......	13	......	......	......	......	......	39
	1	......	29	......	......	......	8	......	......	......	37
	1	......	11	2	......	......	3	1	......	......	17
	1	......	48	......	19	......	15	......	4	......	86
Purple magenta intense	4	......	......	......	300	91	......	......	83	38	512
Purple magenta light-2	1	......	......	......	......	77	......	......	......	......	77

the various compound forms was rather clear. One of the writer's old strain, No. 78, carries speckled Rayed genes for the flower colour pattern. Therefore, when this strain is crossed with speckled, we should obtain speckled Rayed F_1 plants, which give rise to F_2 segregated into 3 speckled Rayed : 1 speckled in proportion, as shown in Table 69.

Table 69.

F_2 from the cross between speckled Rayed and speckled.

Cross	sp Ry	sp	Total
78×445	85	23	108

In hybridization of this strain to faded, the writer obtained F_2 segregating in a trihybrid fashion, as shown by the data in Table 70.

Table 70.

F_2 from the cross between speckled Rayed and faded.

Cross	Ry	+	fd Ry	sp Ry	sp	fd	sp fd Ry	sp fd	Total
SA×78	21	4	17	13	0	1	1	0	57
78×AO	53	22	22	24	9	8	7	1	146
Total	74	26	39	37	9	9	8	1	203

As stated before, when speckled is combined with faded, producing a double recessive, the spots on the corolla are faded in colour, embracing whitish centres. Table 71 contains the similar data with an additional segregation of white-2.

Table 71.

F_2 from the cross between white-2 and speckled Rayed.

Cross	Ry	+	fd Ry	sp Ry	sp	fd	sp fd Ry	sp fd	w2	Total
415×78	64	35	28	28	7	8	3	0	57	230

In Table 72 is shown an F_2 segregating the genes, Rayed, speckled, speckled-reduced and white-1.

Table 72.

F_2 from the cross between white-1 and speckled-reduced Rayed.

Cross	Ry	+	sp Ry	sp	sp-r	w1	Total
SK×440b	33	19	8	5	4	17	89

In this hybridization, the frequency of the segregates is expected to be 108 Rayed : 36 normal : 27 speckled Rayed : 9 speckled : 12 speckled-reduced (including speckled-reduced Rayed) : 64 white-1 in proportion, which practically corresponds with the data above shown.

FLECKED.

The gene flecked is recessive to normal. In Table 73 are collected F_2 showing the segregation of flecked.

Table 73.

F_2 from the cross between flecked and normal.

Cross	+	fl	Total
427×465	252	87	339
465×N	123	40	163
Total	375	127	502

Thus, the genetic relation of flecked to normal is simple, but the property of the gene is made intricate by its high mutability.

Lined.

Lined being dominant to normal, F_1 from them bears Lined flowers. Table 74 contains F_2 showing segregation for Lined and normal.

Table 74.

F_2 from the cross between Lined and normal.

Cross	Ln	+	Total
402×405	54	32	86
N×405	225	55	280
Total	279	87	366

The simple dominant nature of Lined is also testified in Table 75, which contains F_2 with simultaneous segregations of speckled and Rayed.

Table 75.

F_2 from the cross between Lined and speckled Rayed.

Cross	Ry Ln	Ry	Ln	sp Ry	+	sp	Total
78×405	74	26	24	27	13	13	177

The expectation is 27 Rayed Lined: 9 Rayed: 9 Lined: 12 speckled Rayed (including speckled Rayed Lined): 3 normal: 4 speckled (including speckled Lined), and this was practically fulfilled by the data. Table 76 contains F_2 segregated into Lined and flecked.

Table 76.

F_2 from the cross between flecked and Lined.

Cross	Ln	+	fl	Total
465×405	122	39	62	223

The segregating ratio nearly accords with 9 Lined: 3 normal: 4 flecked, indicating a free assortment between Lined and flecked.

STRIATED.

The gene striated acts as a simple recessive to normal. Table 77 includes F_2 segregated into striated and Lined.

Table 77.

F_2 from the cross between Lined and striated.

Cross	Ln	+	sa	Total
401×405	52	7	16	75

The aberration in the segregating ratio is due to linkage between striated and Lined, the frequency of recombination being roughly 16 per cent.

BLIZZARD–1.

The F_2 data of Blizzard F_1 obtained by crossing Blizzard-1 with normal are shown in Table 78.

Table 78.

F_2 from the cross between Blizzard-1 and normal.

Cross	Bz1	+	Total
C15×26	331	108	439
N×C15	265	89	354
Total	596	197	793

Some of F_3 were examined with one of these crosses, as shown by the data in Table 79.

Table 79.

F_3 of cross C15 × 26, showing segregation of Blizzard-1.

F_2 parent	No. families	Bz1	+	Total
Blizzard-1	2	30	......	30
	7	129	45	174
Normal	5	......	77	77

The data do not contain any notable facts beyond proving the simple dominant nature of Blizzard-1 to normal.